

BRIEF COMMUNICATION

ACCUMULATION OF PERIPHYTON ON ARTIFICIAL SUBSTRATA NEAR SEWAGE SLUDGE OUTFALLS AT GLENELG AND PORT ADELAIDE, SOUTH AUSTRALIA.

Two sewage sludge outfalls are sited in seagrass meadows offshore from the metropolitan area of Adelaide (Fig. 1). There has been extensive loss of the seagrasses *Posidonia* (*P. sinuosa* and *P. angustifolia*) and *Amphibolis* (*A. antarctica* and *A. griffithii*) around the Port Adelaide sludge outfall¹ and plants in partially-affected areas have an increased abundance of epiphytes on their leaves².

biomass reflected the pattern of seagrass loss⁴. Lesser effects have apparently occurred on seagrasses near the Glenelg sludge outfall⁵.

The aim of this study was to compare increases in epiphyte biomass at sites adjacent to the two outfalls. Underwater observations indicated that in late summer extensive mats of algae developed throughout the denuded

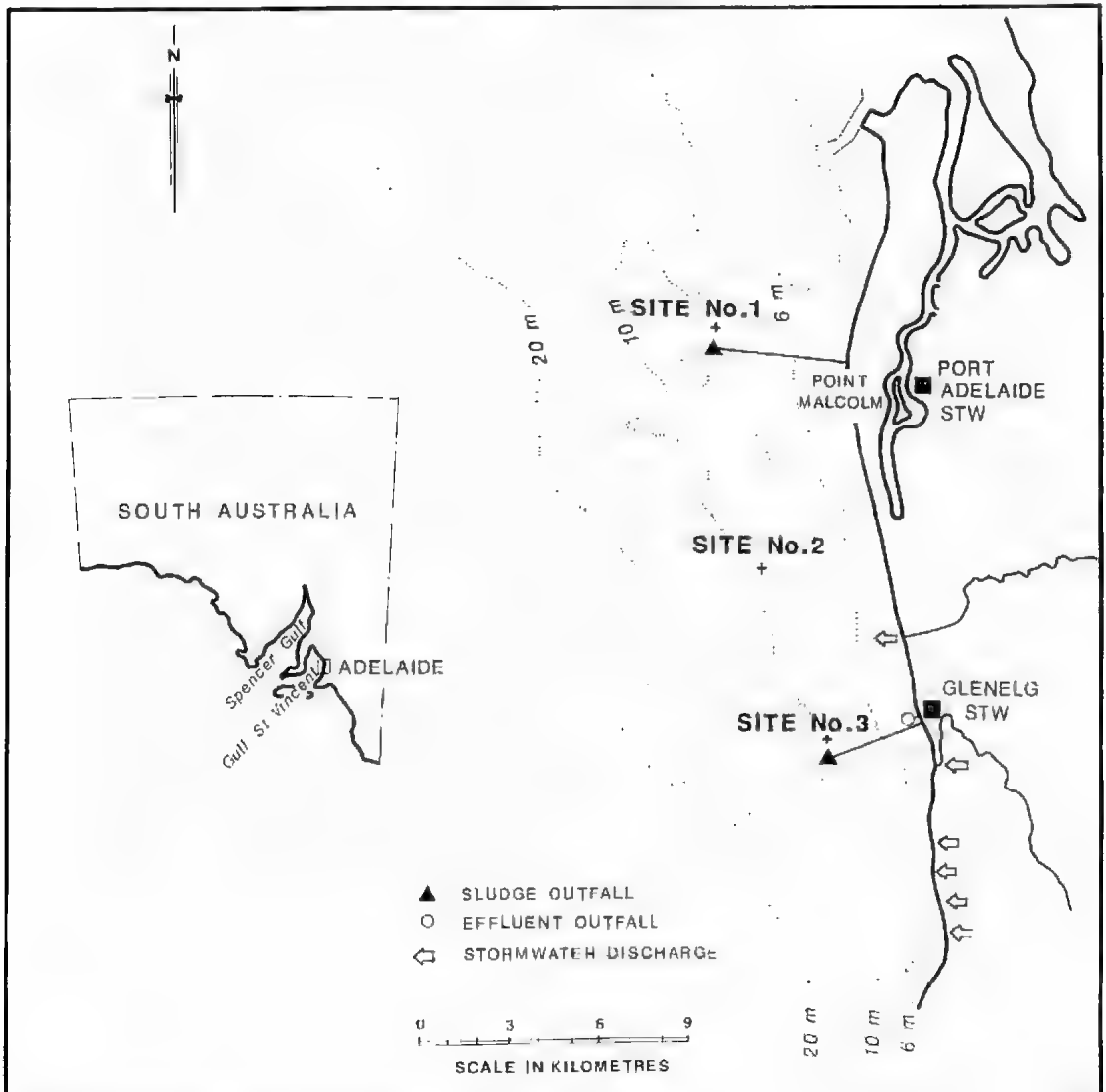


Fig. 1. Study area and sites for deployment of artificial substrata.

Increased growth of epiphytes in response to increased nutrient levels in the water is an apparent cause of the decline of seagrass beds³ and studies with artificial substrata indicated that the rate of increase of epiphyte

area at Port Adelaide. There were signs of increased algal growth near Glenelg but no such mats developed, suggesting that seagrass epiphyte growth may have been reduced in that area.

The accumulation of epiphyte biomass (referred to as periphyton⁶) on artificial substrata was assessed at three sites (Fig. 1). Site 1 was 500m N of the Port Adelaide sludge outfall, coincident with a site used in a previous study⁴. Site 3 was in a similar position relative to the Glenelg sludge outfall and site 2 was a control site situated in apparently healthy seagrass meadows. The depth of water at each site was approximately 13m.

150 substrata were deployed at each site in the early part of November 1986 and sub-sampled at monthly intervals for five months. The dimensions of the substrata, their mode of deployment, collection and processing have been described previously⁴.

The design of this study was simple and it was essentially unreplicated. It did not measure within-site variability nor was an estimate made of variability between different control sites. Underwater observations did, however, indicate that each site was homogeneous over a large area and site 1 has been surveyed in detail¹. Periphyton biomass accumulation has been studied at a number of different control sites^{4,7} and these factors strongly suggested that the above sources of variation were small compared to the variation between experimental and control sites.

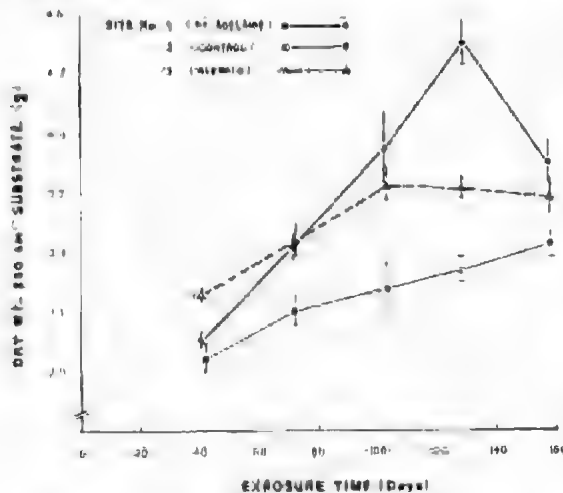


Fig. 2. Changes in dry weight of substrata due to accumulation of periphyton. Mean \pm S.D. ($n = 5$).

Changes in the dry weight of substrata, as a result of the accumulation of periphyton, are shown in Fig. 2. At all times the mean value of dry weight on substrata at the control site was below that recorded at the experimental sites. There were also differences between these two sites. Periphyton biomass accumulation was initially greater at site 3, adjacent to the Glenelg outfall than at site 1, adjacent to the Port Adelaide outfall. After this initial result however, periphyton biomass accumulation was greater and reached higher values at site 1.

Detailed studies at the Port Adelaide outfall have indicated that the most important factor determining the distribution of sludge is tidal flow. It is oriented in a north-south direction and as a result sludge is mostly confined to a narrow strip north and south of the outfall. The

Glenelg outfall has not been studied in the same detail but it is known that the tidal flow is similar to that at Port Adelaide both in strength and direction⁸.

The two experimental sites used in this study were directly north of each outfall and therefore influenced by sludge, a rich source of soluble nitrogen and phosphorus. The composition and concentration of these nutrients in sludge discharged from both Sewage Treatment Works (STW) are similar. Discharge rates are similar but an average of 480kL of sludge is daily discharged from Glenelg STW and 280kL from Port Adelaide STW. It is likely that the initial differences between the substrata at the corresponding sites was a reflection of a greater availability of nutrients at Glenelg.

The differences between the biomass estimates on the substrata at the experimental sites during February and March were associated with distinct changes at the two sites. At Port Adelaide large algae developed and, attached to residual seagrass fibre with its associated mussel beds, formed extensive mats up to 50cm in depth. They were similarly prominent on the artificial substrata. Though it remained visibly greater than at the control site, such growth of algae did not occur around the Glenelg outfall and no large algae developed on the substrata deployed there.

During the last month of exposure, periphyton biomass at Port Adelaide decreased sharply. The early part of autumn is often associated with the first significant storms of the year and large algae are physically removed from the area⁴. Other observations suggested that a similar mechanism may have affected the accumulation of periphyton biomass at Glenelg. When the substrata were sampled divers noted that at Port Adelaide the water column was calm except for tidal movement. At Glenelg a distinct swell was consistently present and this resulted in vigorous motion of the substrata over and above their response to the tide.

While no data are available to compare the incident wave energy at the two sites, the gradient of the seafloor, the presence of offshore shoals at Point Malcolm and the presence of erosion cusps within seagrass beds south of Point Malcolm indicate that wave energy differs between the two sites⁹. It is possible that the initially higher periphyton biomass at the Glenelg site was a reflection of a faster growth rate of algae. As they became larger, however, they were removed by wave action and this resulted in smaller increases in periphyton biomass relative to the Port Adelaide site.

In Western Australia the species of periphyton found on artificial substrata were similar to the epiphytes found on the leaves of *Posidonia australis*¹⁰. It is likely that the same applies in the present study. The response of periphyton to increased levels of nutrients, from sludge, may therefore indicate the response of seagrass epiphytes under the same conditions.

The results presented above suggest that seagrasses in the vicinity of the Glenelg outfall do not accumulate quantities of epiphytes as large as those which accumulated on seagrasses around the Port Adelaide outfall. Individual species of epiphytes may grow faster at the former site but due to greater incident wave energy they are removed from the seagrass before they blanket and burden the leaves as they do at Port Adelaide.

Thus one of the major factors known to cause the decline of seagrass beds seems to be reduced at the Glenelg sludge outfall. This may help to account for the apparently large differences between the extent of seagrass decline

around this outfall⁵ and the extent of decline around the Port Adelaide sludge outfall¹.

I thank Steve Slack and Debra Mooney for their capable assistance.

¹Neverauskas, V. P. (1985) Proc. 1985 Australasian Conf. Coastal Ocean Eng. 1, 193-202.

²Neverauskas, V. P. (1987) Mar. Pollut. Bull. 18, 158-164.

³Cambridge, M. L., Chiffings, A. W., Brittan, C., Moore, L. & McComb, A. J. (1986) Aquat. Bot. 24, 269-285.

⁴Neverauskas, V. P. (1987) Est. Coastal Shelf Sci. 25, 509-517.

⁵Caldwell Connell Engineers. (1981) Sludge disposal from Glenelg STW appendix A. Biological survey at outlet. Rept. to Engineering & Water Supply Dept, Adelaide. Unpubl.

⁶Silberstein, K., Chiffings, A. W. & McComb, A. J. (1986) Aquat. Bot. 24, 355-371.

⁷Neverauskas, V. P. (1987) Port Adelaide Sewage Treatment Works sludge outfall. Effect of discharge on the adjacent marine environment. Final Report. Engineering & Water Supply Dept, Adelaide. Rept. 87/28.

⁸Petrusevics, P. M. (1982) Offshore water studies — metropolitan Adelaide. Coastal Management Branch, Dept Environment & Planning, Adelaide. Rept. 82/9.

⁹Shepherd, S. A. & Sprigg, R. C. (1976) *In* C. R. Twidale, M. J. Tyler & B. P. Webb (Eds) "Natural History of the Adelaide Region". (R. Soc. S. Aust., Adelaide).

¹⁰Silberstein, K. (1985) The effect of epiphytes on seagrasses in Cockburn Sound. Dept Conservation & Environment, Perth. Bulletin. 135.

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BRIEF COMMUNICATION

USE OF GROWTH RINGS TO DETERMINE AGE IN THE FRESHWATER TORTOISE
CHELODINA LONGICOLLIS: A CAUTIONARY NOTE

Counts of laminae growth rings visible on the shells of freshwater North American testudines have been used to determine the ages of individual animals^{1,2}. Periods of brumation coincide with the formation of deep grooves in the epidermis of the shell³, which are initially hidden in the interlaminae seams. They become visible after spring growth commences forming a ridge delineating the outer edge of the groove⁴ and the spreading of the interlaminae seams brings the grooves to the surface. For north temperate species⁵, a "year" can be added to the known age of individuals when the groove becomes visible⁶. The grooves are generally known as growth rings^{6,7}.

Coincident with the recommencement of growth is the formation of a new, deeper layer of epidermis⁸. The margin of the plate of scute epidermis laid down in the previous season's growth is delineated by the growth ring formed at the commencement of the next season of growth⁹. Old layers of epidermis may be retained in terrestrial testudines⁶, but in aquatic species they are usually shed, either as single⁸ or, eventually, multiple layers⁹. Repeated scute ecdysis causes growth rings to weaken then disappear⁷.

Temporary cessation of growth during the growing season may result in the formation in many species of shallow grooves, termed minor growth rings^{8,9}. However, minor growth rings are not associated with the formation of a new layer of epidermis^{8,9}.

Measurement of the gaps between major growth rings, together with counts of their number, have been used to determine growth rates in any particular past year^{7,10}.

Determination of age based on counts of growth rings requires that the number of growth rings produced by a sample of the population over a long period of time be known, and the only satisfactory means of determining the periodicity of growth ring production is to conduct capture-recapture exercises⁷ over several years. Usually, it is assumed that only one major growth ring is formed annually¹¹, and for north temperate species this

assumption is normally valid⁵. However, the assumption that only one growth ring is formed annually by a particular population of a species is not always verified.

The technique of aging has been applied to an Australian species (*Pseudemys umbrina*) by Burbidge¹². The technique of determining growth rates has been applied to *Chelodina longicollis* by Parmenter¹³ and, with reservations, to *C. longicollis* and two other Australian species (*Emydera macquarii* and *Chelodina expansa*) by Chessman¹⁴.

Although verification of the annual deposition of growth rings was undertaken by Burbidge for the populations of *Pseudemys umbrina*¹⁵, there is no clear indication that the periodicity of deposition of growth rings has been determined for populations of *C. longicollis*. Parmenter developed an argument inferring that annual deposition of growth rings occurred in *C. longicollis*, because the species ceases to grow during annual brumation; but there is no evidence that he verified the conclusion¹³. Chessman initially assumed that growth rings were deposited annually, but on comparison with growth rates, as determined on recapture, he concluded that the deposition of growth rings may be affected by growth rate, and that major growth rings may have been confused with minor rings¹⁴.

Parmenter extrapolated from conclusions relevant to North American species to *C. longicollis*; but North American winters are longer and more severe than winters in the range of *C. longicollis*. Daily mean temperatures in the mid west of the United States differ by about 25°C between mid Summer and mid Winter¹⁶ (Table 1), but the difference is only 14°C at Armidale, near where Parmenter undertook his field study. The activity period for *Kinosternon flavescens* in Oklahoma is 140 days², but Parmenter reports an activity period of 250–280 days for *C. longicollis*¹³. Without marked annual temperature cycles the growth of turtle scales is often even and free of interruptions¹⁹. On the coastal plain of the Gulf of

TABLE 1. Daily Mean Temperatures at Meteorological Stations Near Testudine Study Sites

STATION	SPECIES	DAILY MEAN °C MID-SUMMER	TEMPERATURE °C MID-WINTER
Tulsa, Ok, U.S.A.	<i>Kinosternon flavescens</i> ²	27.9	2.9
Lansing, Mi, U.S.A.	<i>Chrysemys picta</i> ⁴	22.1	-4.3
Omaha, Ne, U.S.A.	<i>Chelydra serpentina</i> ⁶	25.8	-5.4
St Louis, Mi, U.S.A.	<i>Pseudemys scripta</i> ⁷	26.4	-0.1
Kansas City, Ks, U.S.A.	<i>Terrapene ornata</i> ³	27.2	-0.7
Phoenix, Az, U.S.A.	<i>Kinosternon sonoriense</i> ²⁰	32.9	10.4
New Orleans, La, U.S.A	<i>Sternotherus carinatus</i> ¹⁷	28.4	13.3
Colon, Panama	<i>Pseudemys scripta</i> ⁹	26.6	26.8
Armidale, N.S.W., Aust.	<i>Chelodina longicollis</i> ¹¹	20.4	6.6
Melbourne, Vic., Aust.	<i>Chelodina longicollis</i> ¹⁴	19.9	9.6
Mildura, Vic., Aust.	<i>Chelodina longicollis</i> ¹⁴	24.1	10.1
Adelaide, S.A., Aust.	<i>Chelodina longicollis</i> ¹⁸	22.6	11.2

Source of climatic data — "World Survey of Climatology", ed. H.E. Landsberg, Elsevier, Amsterdam, (1971).

References are to studies undertaken in vicinity of stations.